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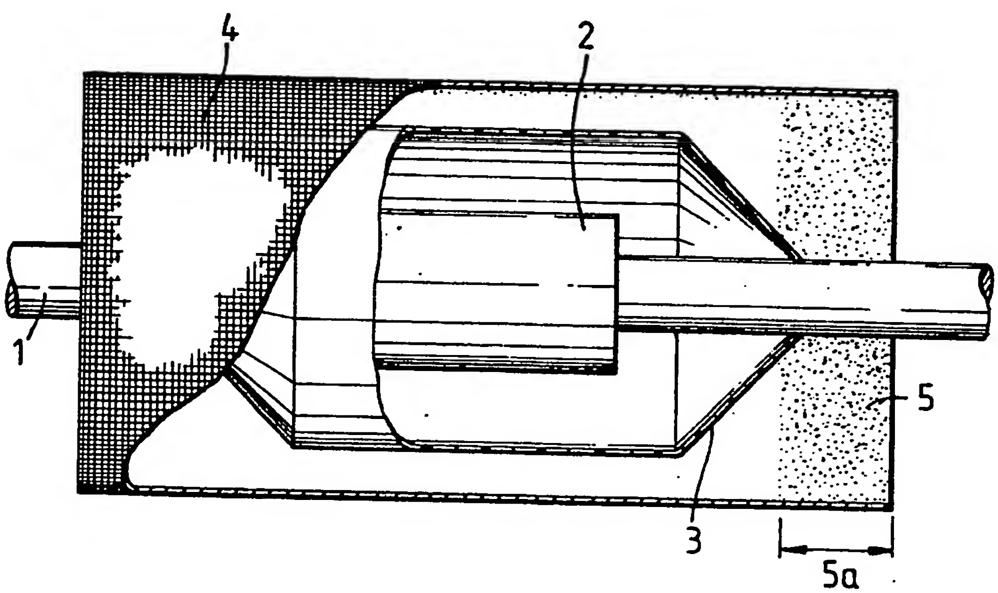
(54) **Recoverable fabric sleeve.**

(57) A sleeve suitable for making a cable splice case comprises a matrix material and a recoverable fabric by virtue of which the sleeve is recoverable. The sleeve comprises recoverable weft fibres in bundles of 2-6 running circumferentially, and longitudinal heat-stable warp fibres.

Fig. 1.



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RECOVERABLE FABRIC SLEEVE

The present invention relates to a recoverable fabric sleeve for the environmental protection of junctions in elongate substrates, such as splices in cables, particularly in telecommunications cables.

It is frequently necessary to protect such junctions against the environment in order that the cables or other substrates may continue to function properly. Protection generally has to be provided against moisture, corrosive chemicals as well as insect and animal damage etc. The intention when enclosing a junction such as a cable splice is to make good the original cable insulation that had to be removed in order to connect the conductors, and it is generally required that the life-time of the seal provided by the new enclosure be comparable to that of the original cable insulation. It will be appreciated therefore that the material of the enclosure must provide a highly resistant barrier for a considerable period of time.

One way of providing such a barrier is to install around the cables a splice case comprising an imperforate sleeve of a modified polyolefinic material in conjunction with a high performance adhesive. Such sleeves are conveniently produced by extruding a continuum of material. The sleeve is preferably made recoverable so that it can be shrunk (or otherwise recovered) into close contact with the cables.

There is a further consideration relevant to the design of enclosures for cable splices, and that is the ability to retain pressure. Many types of cables and splice cases are pressurised during use, are assessed in terms of pressure retention to determine their quality, or become subject to incidential pressurisation during use. The importance of this consideration is of course different in each of these three situations, but it is accepted that the ability to retain some degree of pressure is a necessary feature of a splice case if environmental protection is to be achieved.

The most stringent requirements are for a splice case for pressurised cables, such as main cables in a telecommunications system. These cables are pressurised to prevent ingress of water in the event of damage and to provide a means of fault detection. Here the product must withstand a pressure of the order of 10 psi (70 kPa) throughout its life, and a functional test designed to mirror such long term performance requires impermeability at, say, 70 kPa over 10 eight hour cycles between -40°C and +60°C in air (Bell cycle). An alternative cycle is in water over four hours at 105 kPa between 5 and 50°C. In addition to this cyclical environmental test, the product may be tested for integrity by pressurisation at 150 kPa in water for about 15 minutes at 23°C. No leak should be observable. A product that is to operate continuously at pressure should also possess long term creep resistance if it is not to become significantly distorted during use.

In telecommunications distribution cables, for example, an ability to retain pressure is required as an indication of completeness of environmental sealing, although the cables are not pressurised during use. Various temperature/pressure cycles have been devised for this purpose, and one that is preferred is a modified Bell Cycle which involved temperature variation from -40 to 60°C over 8 hours at an air pressure of 40 kPa. The splice case should show no leak after 10 cycles. An alternative cycle is a temperature variation between room temperature and 70°C at a pressure of 105 kPa over 4 hours.

These and other cable splice cases may become pressurised through being exposed to sunlight, or through the heat involved in the last stages of heat recovery when the seals to the cable have been formed. In such cases it is necessary that the splice case be able to maintain this temporary, and generally rather low, pressure if the environmental seal is not to fail.

UK Patent application 2135836 discloses a splice case or other hollow pressure vessel capable of presure retention and made from a recoverable fabric. Such a splice case comprises a recoverable sleeve that can be wrapped around a cable splice and shrunk to seal to the cable. Installation is simple and the product is reliable even under unfavourale conditions.

Specific designs disclosed in the prior art may not be ideal for cheap, rapid manufacture and may not have sufficiently high recovery ratios for some uses.

We have now designed a recoverable wrap-around sleeve of specific design that can overcome problem of certain prior art designs. This is achieved by employing recoverable weft fibres in bundles, particularly at low weave densities.

This invention provides a heat recoverable tubular or wrap-around sleeve having a recovery ratio of at least 40% and being suitable for enclosing a junction between elongate subsrates, which comprise:

(a) a polymeric matrix material; and

(b) a recoverable fabric by virtue of which the sleeve is recoverable and which is rendered impervious by the matrix material, comprising heat recoverable weft fibres extending around the circumference of the sleeve in bundles of 2-6, and non recoverable warp fibres extending along the length of the

sleeve.

The invention also provides a heat-recoverable tubular or wraparound sleeve having a recovery ratio of at least 40% and being suitable for enclosing a junction between longate substrates, which comprises:

(a) a polymeric matrix material; and

(b) a recov rabl fabric by virtue of which the sleeve is recoverabl and which is rendered impervious by the matrix material, comprising 24-35 heat recoverable fibres per cm in one direction and 2-6 non-recoverable fibres per cm in a substantially perpendicular direction and having a float of at least 2 in the recoverable fibres; and

(c) optionally a liner for the sleeve, the liner having a central region of larger cross-section, and end regions of smaller cross-section which provides transitions from the central region to the substrate and which can locate the linear with respect to the substrate.

The extend to which the fabric need be impervious will of course depend on the use of the sleeve. Where the sleeve is used to seal a splice between pressurized cables a high imperviousness will be desirable if pressurization gas is not to be wasted. In other situations imperviousness to water, oil, fuel or hydraulic fluids may be required. A degree of perviousness will, in general, be tolerable depnding on the nature of the substrate and on the length of time that the assembly will be in use.

The means for rendering the fabric substantially impervious is a polymeric material that is laminated to and may extend throughout the recoverable fabric. We prefer that a true composite structure be formed between the recoverable fabric and a polymeric material by means of which it is rendered impervious. We prefer that the polymeric material provides a matrix material through which the fabric extends (although the matrix material may be merely bonded to one or both sides of the fabric) and therefore that at least part of the fibre material be chemically and/or physically compatible with the polymeric material. By physically compatible we mean that the relevant properties of the two materials are similar or identical during lamination, recovery and use. Chemically similar materials are preferred, for example both recoverable fibres and matrix may be polyolefins, and preferred materials are high density and low density polyethylene respectively. The skilled man would be able to select other suitable pairs of materials. We have found that a recoverable fabric rendered impervious can have excellent pressure retention where imperviousness to air is required. The ability of the sleeve to retain pressure is not simply a question of porosity of the material, although it must ultimately be substantially free from holes, but is determined also by the ability of the material to withstand hoop stresses that are generated by pressure within the sleeves. It is with regard to this second effect that recoverable fabrics have been found to be particularly good. Fabric sleeves of small thickness have been found to be able to resist high pressures without significant ballooning or creep. It is furthermore surprising that this beneficial feature can be made use of in spite of the initial porosity of fabrics.

The sleeve and any liner may each be made in tubular form or wrap-around form. Wrap-around sleeves and liners are preferred since they can be installed around substrates having no free ends or where space is limited.

Several matters are to be borne in mind when designing the recoverable sleeve, and the first to be considered will be recovery ratio. The recovery ratio should be sufficient to allow the sleeve to be installed over the largest parts of the substrate and to recover into contact with the smallest parts. In a splice between telephone cables, the splice bundle will in general be from 2-6 times the cable diameter, and a sleeve having a recovery ratio of at least this size will be suitable. The sleeve preferably does not recover into engagement with the splice bundle, since if it did damage would result. Also, it is desirable that the splice case be re-enterable without damage. Thus, the final structure is preferably hollow. The extent of recovery can also be expressed by quoting the change in a dimension as a percentage of the recoverable dimension before recovery. Expressed thus, recovery is at least 40%, particularly at least 50%, more particularly at least 75%. We have found that by using the weave designs and fibre types and tex values disclosed herein that recovery ratios of at least 75%, often also at least 77.7% (4.5:1), and frequently at least 78% can be achieved in a laminated composite product. Such high values are very difficult if not impossible to achieve using prior art designs. High recovery ratios allow fast installation times, require fewer sizes of product to cover a given range of substrate sizes (thus reducing inventory) and also may allow the use of a thin aluminium foil in conjunction with the fabric is a strengthening layer (we have found that with lower recovery ratios a metallized polymeric layer had to b used).

When the fiber is cross-linked by irradiation it is possible to incorporate the cross-linking step into the overall manufacture of the fibre, but at present we prefer to weave the fabric and then irradiate th fabric. The fibre can be extruded, stretched at a temperature below its melting temperature, preferably by an amount of from 800-2000%, then woven and th n subjected to irradiation to effect cross-linking. An alternative way of making the fibre is to extrude the material, irradiate to cross-link, then heat the fibre

preferably to above its m lting temperature, stretch the fibre, and then cool. HDPE fibres are preferably irradiated with a dose of from about 5 to about 35 megarads, more preferably from about 5 to about 25 megards, and most preferably from about 7 to about 18 megarads especialy from 6 to about 10 megarads. The gel content that results is preferably at least 20%, more preferably at least 30%, and most preferably at least 40%. In practice a maximum of abut 90% will be sufficient for most purposes.

When recoverable by heat, the recovery temperature is preferably 60°C or more, more preferably from 80-250°C, such as 100-150°C.

In general, the fabric will be constructed so that the recoverable fibres can effectively run at least in the direction where recovery is required. In the weave, therefore, the warp only, or the weft only, or both weft and warp, may be recoverable. In one embodiment, we prefer that the heat-recoverable fibres are in the weft only. Providing the heat recoverable fibres in the weft only enables us to make tubular or wraparound articles in which the recoverable fibres extend around the circumference of the article, in a continuous process, the articles later being cut to their desired length. In more complicated weaves, such as a triaxial weave, one or both warps may be recoverable. An advantage of the use of fabrics is that perfect uniaxial recovery, or a chosen split in recovery between two directions, may be achieved.

According to one aspect of the invention there are 10-35 heat recoverable fibres per cm, and the fibres pre ferably have a dimeter of from 0.2-0.5mm. Preferably in the case of 0.3mm diameter fibres there are 24-35, especially 26-30 heat recoverable fibres per cm, for example about 28-30 28.3 being chosen in one embodiment. Preferably the heat recoverable fibres have a tex (weight per cm) of 60-150, for example 60-100 especially about 64, although heavier fibres, eg 0.4-0.5mm may be used with advantage at lower weave densities. Higher weaving speeds can thus be achieved. With such fibres, weave densities of 10-25 fibres per cm may be preferred.

According to the first aspect of the invention there are 2-6 non recoverable fibres per cm. Preferably there are 3 to 4 non recoverable fibres per cm. For example about 3.54. Preferred tex for the non-recoverable fibres include the following: 1,2 or 3 x 34 and 1,2, or 3 x 68.

The fibre size and weave densities are preferably chosen to produce a low cover factor (the percentage of a plane in which a sample of the fabric lies that is covered by fibre thereof) of the fabric of 50-85%, more preferably 55-70% since this can allow higher recovery ratios in spite of the reduced amount of recoverable fibre.

The fibres used to produce the recoverable fabric may be monofilaments or multifilaments, including spun, staple yams or yams produced by fibrillation, for example from film. In the case of multifilaments, the above weave densities refer to the monofilaments. Greater flexibility can be attained using multifilament yams, although problems can be encountered in cross-linking due to the high surface area. Examples of polymeric materials that may be used as the recoverable fibres include polyolefins such as polyethylene (especially HDPE) and polypropylene, polyamides, polyesters and fluoropolymers such as FEP, ethylene perfluoro copolymer, polyvinylidine fluoride and TFE copolymers. The recovery temperature, by which we mean the temperature at which recovery will go substantially to completion, is preferably 60°C or more, more preferably from 80-250°C, most preferably from 100-150°C.

The heat-recoverable fibres, which are preferably provided in the weft only, are preferably provided in bundles of 2-6, especially in bundles of 4. The bundle is preferably woven so that each fibre in the bundle lies directly adjacent its neighbour, so that the bundle is flat, and substantially parallel to the plane of the fabric. Providing the heat recoverable fibres in bundles means that weaving times are reduced, when the recoverable fibres are in the weft, compared to the weaving times necessary if the fibres are arranged individually. Also, we have found that for a tubular or wraparound article where the heat recoverable fibres extend around the circumference and heat stable fibres along the length of the article that longitudinal shrinkage of the article on recovery is reduced if the heat recoverale fibres are in bundles, compared to the longitudinal shrinkage experienced if the heat recoverable fibres are individual. Longitudinal shrinkage is though to occur due to increase bending or crimping of the non recoverable fibres as a result of tightening of the fabric caused by recovery of the recoverable fibres. Longitudinal shrinkage is for many applications disadvantageous. It may, for example, result in wrinkling, particularly at a transition zone between large and small cross sectional areas of an article.

Non-recoverable fibres are used together with the recoverable fibres. The following non-recov rable materials may be regarded as illustrative: glass fibres, carbon fibres, wires or other metal fibres, p lyesters, aromatic polymers such as aromatic polyamides for example Kevlar (trade name), imides and ceramincs. The non-recoverable component may be permanent, giving the recovered article enhanced strength etc., or may be present in discrete form only to locate the recoverable component during installation.

The means by which the fabric is rendered substantially impervious is a polymeric material laminated to and which preferably extends throughout the fabric. The sleeve of the invention thus preferably comprises a composite structure of a heat-recoverable fabric and polymer matrix material wherein:

(a) the heat recoverable fabric comprises fibres that will recover when heated, the fibres having a recovery stress Y of at least 1×10^{-2}, preferably at least 5×10^{-2} more preferably at least 1MPa at a temperature above their recovery temperature; and

(b) the polymer matrix material has an elongation/temperature profile such that there exists a temperature (T) which is at or above the recovery temperature of the fibres at which temperature the polymer matrix material has an elongation to break of greater than 20% preferably greater than 100%, especially from 400-700% and a 20% secant modulus X of at least 10^{-2} MPa (measured at a strain rate of 300% per minute), and at which temperature the inequality is satisfied:

$$\frac{X}{Y} \left(\frac{1 - R}{R}\right)$$

is less than one, preferably less than 0.5, more preferably less than 0.05.

Wherein R is the mean effective volume fraction of heat-recoverable fibres in the composite structure along a given direction based on the total volume of the composite structure, or relevant portion thereof.

Such a recoverable composite structure can be made by applying a polymeric material to cross-linked recoverable fibres and then carry out further cross-linking.

The fibres are desirably cross-linked to increase their post-recovery strength, and a recovery stress of at least 0.1 MPa, preferably 0.5 to 5 MPa will generally be suitable. The polymeric material is desirably cross-linked to prevent it dripping or running during heat recovery, particularly during heat recovery by means of a torch. Too much cross-linking of the polymeric material will, however, reduce the recovery ratio of the composite structure. This can give rise to a problem since a different extent of cross-linking treatment may be required in the fibres and the polymeric material. This is the reason for the two cross-linking steps being carried out separately in the embodiment just described.

The composite structure may, nonetheless, be produced using a single cross-linking step if the beam response of the recoverable fibres relative to that of the polymeric material is such that a post-irradiation recovery stress of the fibres, per se, of at least 1 MPa can be reached before the recovery ratio of the composite structure is reduced to a value of 70% of that of the unirradiated composite structure.

The relative beam response may be produced by the presence of prorads in the recoverable fibres and/or antirads in the polymeric material.

In a preferred embodiment of the invention the fabric is incorporated into a flexible recoverable composite structure comprising the recoverable fabric and a polymeric matrix material laminated thereto, in which:

(a) the recoverable fabric comprises a cross-linked recoverable polyolefin having a recovery stress of 0.5 to 5 MPa.

(b) the matrix is cross-linked such that the recovery ratio available in the composite is at least 65% of that available in the free fabric, and the polymeric matrix material, per se, after irradiation has room temperature elongation of 400-700% measured at a strain rate of 300%.

Irradiation, in addition to providing one means of cross-linking, can provide other features in the composite structure. If the fibres are irradated, particularly in the presence of oxygen, before application of the polymeric material then a change in the surface properties of the fibres may occur (such as oxidation) which improves adhesion between the fibres and the polymeric material. An irradiation step after application of the polymeric material may also aid such bonding by forming a cross-linked bond between the two components of the composite structure.

The polymeric matrix material may be thermoplastic or elastomeric. Examples of thermoplastic materials include: ethylene/vinyl acetate copolymers, ethylene/ethyl acrylate copolymers, LLDPE, LDPE, MDPE, HDPE, polypropylene, polybutylene, polyesters, polyamides, polyetheramides, perfluoroethylene/ethylene copolymers, and polyvinylidene fluoride. The following is a list of preferred elastomeric materials: ABS block copolymers, acrylics including acrylates, methacrylates and their copolymers, high vinyl acetate copolymers with ethylene, polynorbornene, polyurethanes and silicone elast mers. These materials (or part of them) are preferably cross-linked, and this is conveniently carried out by subjecting the fabric to a suitable cross-linking agent after the fabric has been rendered impervious by incorporating the polymeric material.

The amount of polymeric material used should be suffici nt to render the fabric sleeve substantially impervious to air when it is recovered. It is possible, therefore, for the polymeric material to b a discontinuous coating or impregnation before recovery, and optionally to melt or soften sufficiently to be brought together on recovery to provide a substantially impervious barrier. We prefer, how ver, that th composite of fabric and polymeric material be substantially impervious before as well as after recovery. The thickness of the polymeric material should be great enough to allow the desired pressure, if any, to be retained, but small enough to allow the fabric to recover to the desired extent. The composite desirably recovers as a unit with no appreciable drawing-through of fabric within the matrix. A suitable thickness of polymeric material is 0.5-1.5mm preferably about 0.2mm on the inside of the sleeve and about 0.5mm on the outside of the sleeve. We have found that an unstressed layer of a polymeric material of thickness of at least 0.03mm especially 0.2 to 2.0mm on the outside surface of the sleeve provides a considerable improvement in the ease with which the fabric can safely be recovered using a torch such as a propane torch. Such polymeric layer will generally soften during recovery but has a sufficiently high viscosity that is retained by the fabric. A polymeric material initially having a sufficiently high viscosity may be used, or the viscosity of a low viscosity material may be increased by cross-linking, particularly by beaming.

Where two layers of polymeric material are provided one on each side of the sleeve, both layers may be cross-linked, for example by irradiation, or only the layer on the outer surface of the sleeve.

The sleeve is preferably provided with a strengthening layer that is capable either of minimising adhesive burst-through on recovery, or reducing moisture vapour transmission of the article in service or improving creep resistance in service, or of improving pressure retention of the article in service, or any combination thereof. Such a layer is described in copending British Patent Application No 8625126 filed 20th October 1986 (B131), the disclosure of which is incorporated herein by reference.

The sleeve is preferably coated with an adhesive on its inside, ie. on that side which will face the substrate to be enclosed,although the polymeric material providing imperviousness may alone provide the desired adhesiveness under installation conditions. Heat-activatable adhesives are preferred, especially hot-melt adhesives such as polyamides and EVAs.

Where an enclosure has to be build around a simple end-to-end joint between two cables a simple sleeve can be used which shrinks into contact with each cable. However, problems may arise where two or more cables or other substrates have to be sealed at one position. This problem, which is known as branch-off, occurs in a cable splice where one cable is divided into two. This problem can be overcome by providing means such as a clip for holding together circumferentially spaced portions of an outlet of the fabric sleeve to close at least partially the crutch region between the diverging cables.

The problem of branch-off can, however, be overcome by producing the fabric sleeve in the correct shape to accomodate two or more branching substrates.

The following example is given to illustrate a cable splice case built from peferred materials.

Example

The following HDPE monofilament was chosen to provide the recoverable component of a broken twill 2/2 weave.

MN	24500
Mw	135760
Mz	459000
Mp	64400
D	5.378
Initial Modulus (MPa)	3881.3
% Elongation (21°C)	21
Tensile Strength (MPa)	534.4
Monofilament dia (MM)	0.38

This fibre had the following properties:

Fibre Properties

Radiation Dosage (Mrads)

Property	0	8	16	32
100% Modulus (MPa)		0.13	0.3	0.42
Tensile Strength (MPa)		0.93	1.4	1.46
elongation to Break (%)		1480	924	754
Gel Content (%)		27.0	58.0	67.0
Reocvery Force (MPa)		1.17	1.2	1.3
Recovery (%)		89	88.5	88.5

The HDPE fibres were arranged in bundles of 4, and woven with non-recoverable glass fibres to produce a broken twill 2/2 weave, ie a broken twill having a float of 2. In each case the recoverable HDPE bundles were the weft fibre and glass was the warp fibre, and the float was in the weft.

The glass fibres are preferably ones having the desigation EC 9 34 tex x 25152. This type of designation is standard and will be understood by those in the art. Briefly it has the following meaning Ec refers to the tex value of the bundles of filaments, x 2S refers to the number of monfilaments in a bundle, 152 refers to 152 twists in the bundles per metre.

The warp density was 3.5 ends/cm, and the weft density was about 28.4 ends per cm (7.1 bundles of 4 fibres per cm). Afte irradiation at an electron beam dose of 7.8 megarads, the value shown on an integrity hold-out test was 6.5-9 Newtons per 80 fibres of the fabric.

The fabric was rendered substantially impervious by laminating to it a low density polyethylene at a thickness of 0.3mm on one side and 0.6mm on the other side. Lamination was carried out at such a temperature, pressure and processing speed that the material permeated the interstices of the fabric but no recovery occurred. The resulting composite was subjected to a second irradiation step with 6 MeV electrons in air at room temperature at a dose rate of 0.24 Mrads/min for time sufficient to produce a radiation dose of 2.0 - 3.0 Mrads.

The resulting composite material had a recovery of 75%. The composite material was used to produced a wrap-around sleeve suitable for use as a splice case for enclosing a splice between two telephone cables. Closure members were attached to or formed at opposing edge portion of the sleeve such that the recoverable fibres ran from one closure member to the other. The sleeve could therefore be held in a wrapped around configuration by sliding a closure channel over the two closure members. The sleeve was therefore radially recoverable. Prior to attachment of the closure members, the composite material was coated with a hot-melt adhesive in each side which would be inwardly facing when the sleeve was in the wrapped around configuration.

The adhesive used was a polyamide, modified with up to 1% of an acrylic rubber, applied to a thickness of 0.5mm.

In order to reduce the amount of adhesive required, it was coated only around each end of the sleeve, in general this will require some sort of lubricant layer over the rest of the sleeve or over the liner. Adhesive is required at the ends for bonding to the spliced cables that will enter and leave the installed sleeve. If desired, however, the adhesive may be coated over the entire internal surface of the sleeve, and such adhesive may act as the lubricant mentioned above.

The sleeve was used in conjunction with a liner which comprised an aluminium canister of about 75% of the length of the sleeve and having crowned ends which could be deformed to provide smooth 30°C transitions. The diameter of the canister was chosen to be about 75-90% of the diameter of the assembled sleeve in order to ensure some degree of unresolved recovery.

The invention is further illustrated with reference to the accompanying drawings, in which:

Figure 1 shows a joint between two substrates surrounded by a liner and an unrecovered sleeve;

Figure 2 shows a similar joint but with the sleeve after recovery;

Figure 3 shows a cabl splice partially surrounded by a wrap-around liner and a wrap-around recoverable sleeve;

Figure 4 shows in partial transverse cross-section a wrap-around sleeve and liner; and

Figures 5 to 7 show the fabric design for broken twill 2/2 twill 2/2 and satin 4 respectiv ly.

Two substrates 1 are joined at a joint region 2 and surrounded by a liner 3 and recoverabl fabric sleeve 4 comprising a weft of 10-35 heat recoverable high density polyethylene fibres per cm in bundles of 2-6, preferably 4 and a warp of 2-6 glass fibres per cm. The weave is a broken twill 2/2 having a float of 2. In Figure 1 the sleeve is shown before recovery, and in Figure 2 it is shown after recovery. In Figures 1 and 2 an adhesive 5 can be seen bonding the sleeve to the substrates 1 and to the liner 3. The adhesive is preferably supplied coated to the internal surface of the sleeve at least at its ends as indicated at 5a. Where recovery is initiated by heat, the adhesive is preferably heat-activatable so that the single step of heating causes recovery if the sleeve and activation of the adhesive.

A thin layer of adhesive may cover the entire surface of the sleeve, and thicker layers of adhesive be provided at regions 5a.

In Figure 3 the substrates 1 are shown as multi-conductor cables, and region 2 is a splice bundle joining the two cables. In this Figure both the liner 3 and the fabric sleeve 4 are wrap-around. The liner is hinged at 8 and has castellated edges 9 to ensure rigidity when closed. The sleeve is provided with closure members 6 at its longitudinal edges which can be held together with an elongate channel of C-shaped cross section (not shown) to maintain the sleeve in a wrapped around configuration. Other types of closure, for example a zipper, may be used and in general what is preferred is a mechanical closure for maintaining edge regions of the fabric in proximate relationship during recovery. The liner has crowned ends 7 which provide transitions for its central region to the cables 1 and which locate the liner with respect to the cables, thereby allowing production if deired, of a hollow pressure vessel having outlet portions only recovered into engagement with the cables.

Figure 4 shows a recoverable wrap-around fabric sleeve 4 and liner 3 in partial transverse cross-section. The closure is formed by means of closure members 6 preferably elongate members running substantially the length of the sleeve and attached to edge portions of the sleeve 4 and held together by a closure channel 10. The closure members comprise a fabric strip 11 stitched or stapled onto each edge of the sleeve. A rod, rope or cord may be used to form a thickened edge region to each strip 11 as indicated at 12.

Any gap between the closure members 6 may be sealed by a flap 13 that runs the length of the sleeve and bridges the closure members.

The fabric of the sleeve may be seen to comprise circumferential bundles of recoverable fibres 15, (not shown individually), for example crosslinked high density polyethylene interwoven with circumferential non-recoverable fibres 14, for example glass, rayon or Kevlar. The float of 2 in the weft is also reflected in the warp. and can be seen in the drawing.

The liner 3 comprises an aluminium canister 3a to which is laminated a film of a suitabe material such as an ethylene copolymer.

The fabric of the sleeve is laminated by a double lamination process. The outside of the sleeve is coated with a low density polyethylene 16 of thickness about 0.6mm,and the inside with a low density polyethylene 17 of thickness about 0.3mm.

If desired, the construction of the sleeve may contain one or more additional layers. For example, a film may be provided between the composite structure of fabric and polymeric matrix material, and the internal layer of hot-melt or other adhesive. Such a film is preferably thin in order not to restrict shrinkage of the sleeve. If such additional layer or layers are used one may use a very loose or open weave, for example a satin or leno (or a weft or warp insertion knit) of weave density of say, 10-25 heat-recoverable fibres per cm and, say, 1-6 non-recoverable fibres per cm. Stability of the product is increased using the extra layer, adhesive burst through is reduced and air leaks are reduced. The film may be made of any suitable material that has one surface that can adhere to the composite structure (fibre or matrix) and an opposite surface that can adhere to the adhesive. Examples include aluminium, mylar, nylon 6, nylon 6,6, thermoplastic polyurethanes or two or more of these. We have found that the more open weavs (lower cover factor) of lower weave densities are able to be used with aluminium film whereas prior art weave designs require the more flexible polymeric films instead. This is due to the higher recovery ratios of the open weaves enabling proper deformation of the thicker aluminium films.

The fabric used in this specific example is a brok n twill 2/2 (two up/two down),in which the heat recoverable fibres are in the weft and the non-recoverable fibres are in the warp. The fabric design has a float of 2. The fabric design is illustrated in Figures 5a and 5b. Figure 5a is a block diagram as used in the fabrication industry. The 4 by 4 square block illustrates the subsequent passage of 4 adjacent fibres in each of the warp and the weft. A white square illustrates a fibre passing over the fibre in the other direction, and a hatched square a fibre passing under the fibre in the opposite direction. This is also illustrated in the more

literal diagram Figure 5b in which the heat recoverable fibres are referenced 20 and the non recoverable fibres 21. The heat recoverable fibres in bundles (fibres (not shown individually) extend in the weft which has been depicted as the direction running from left to right of th page. Thus in rows 1 and 3, the heat recoverable fibres pass alternatively under and over individual non-recoverable fibres, while in rows 2 and 4 th heat-recoverable fibres pass alternatively und r and ov r pairs of non recoverable fibres. The 2/2 ref rences denotes this 2 over, 2 under configuration. Th float is thus 2.

Figures 6a and 6b show the corresponding design for twill 2/2 in which the float is also 2. Figure 7a and 7b show the corresponding design for satin 4 in which the float is 3, that is a heat recoverable fibre passes over 3 nonrecoverable fibres and then under one.

For the avoidance of doubt it is here indicated that the invention provides a fabric sleeve suitable as a splice case that can embody any one or more of the features disclosed herein. For example any one or more of the materials, weave designs, the inclusion of an additional layer, closure geometries or configurations, processing steps or ancilliary components may be selected.

Claims

1. A heat-recoverable tubular or wrap-around sleeve having a recovery ratio of at least 40% and being suitable for enclosing a junction between elongate substrates, which comprises:

(a) a polymeric matrix material; and

(b) a recoverable fabric by virtue of which the sleeve is recoverable and which is rendered impervious by the matrix material, comprising heat recoverable weft fibres extending around the circumference of the sleeve in bundles of 2-6, and non recoverable warp fibres extending along the length of the sleeve.

2. A sleeve according to claim 1, having a recovery ratio of at least 75%.

3. A sleeve according to claim 1 or 2, having a recovery ratio of at least 77.7%.

4. A sleeve according to any preceding claim, in which the fabric has from 10-35 bundles of recoverable fibres per cm.

5. A sleeve according to claim 4, in which the fabric has from 10-25 bundles of recoverable fibres per cm.

6. A sleeve according to claim 5, in which the fabric has from 14-18 bundles of recoverable fibers per cm.

7. A sleeve according to any preceding claim in which the fabric comprises recoverable fibres having a diameter of from 0.2-0.5mm.

8. A sleeve according to claim 7, in which the fabric comprises recoverable fibres having a diameter of from 0.3-0.4 mm.

9. A sleeve according to any preceding claim having a cover factor of 50-85%.

10. A sleeve according to any preceding claim in which the fabric has from 2-6 non-recoverable fibres per cm.

11. A sleeve according to any preceding claim in which the fabric has a float of at least 2 in the recoverable fibres.

12. A sleeve according to any preceding claim wherein the weave is one of the following design: broken twill 2/2, twill 2/2, satin 4, satin 5.

13. A sleeve according to any preceding claim, in which the fibres are cross-linked.

14. A sleeve according to any preceding claim, in which the recoverable fibres comprise polyethylene.

15. A sleeve according to any preceding claim, in which the fabric contains glass fibres or fibres of an aromatic polyamide or of a polyester as the non-recoverable fibres.

16. A sleeve according to any preceding claim, having an internal coating of a heat-activatable adhesive.

17. A junction between elongate substrates when enclosed by a sleeve according to any preceding claim.

18. A junction according to claim 17, in which the substrates comprise telecommunications cables.

19. A method of enclosing an elongate substrate, which comprises:

(a) installing around the junction of a liner having a central region of larger cross-section, and end regions of small r cross-section which provide transitions from the central region to th substrates and which locate the liner with respect to the substrate;

(b) installing around the liner sleeve according to any of claims 1-16; and

(c) recovering the sleeve to cause the sleeve to engage the substrates at each side of the junction.

Fig.1.

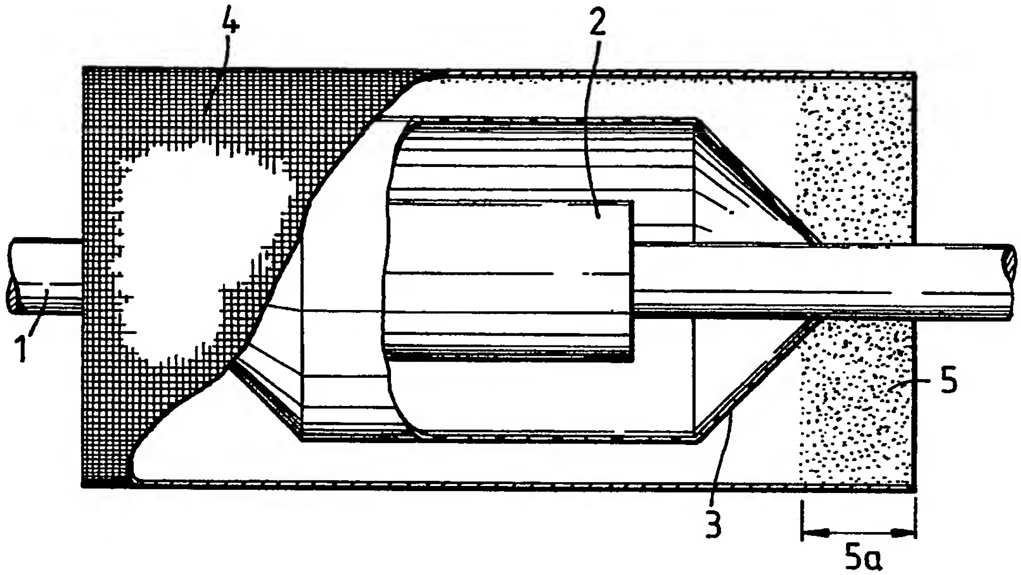


Fig.2.

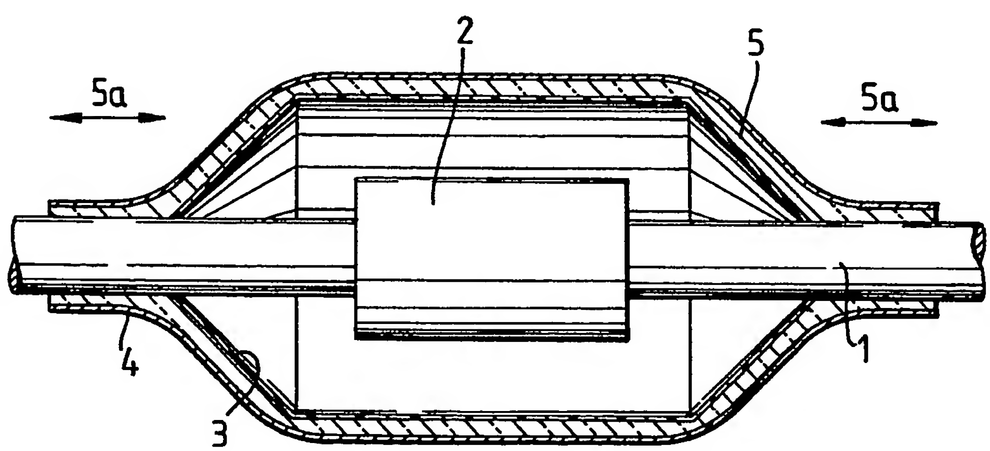


Fig.3.

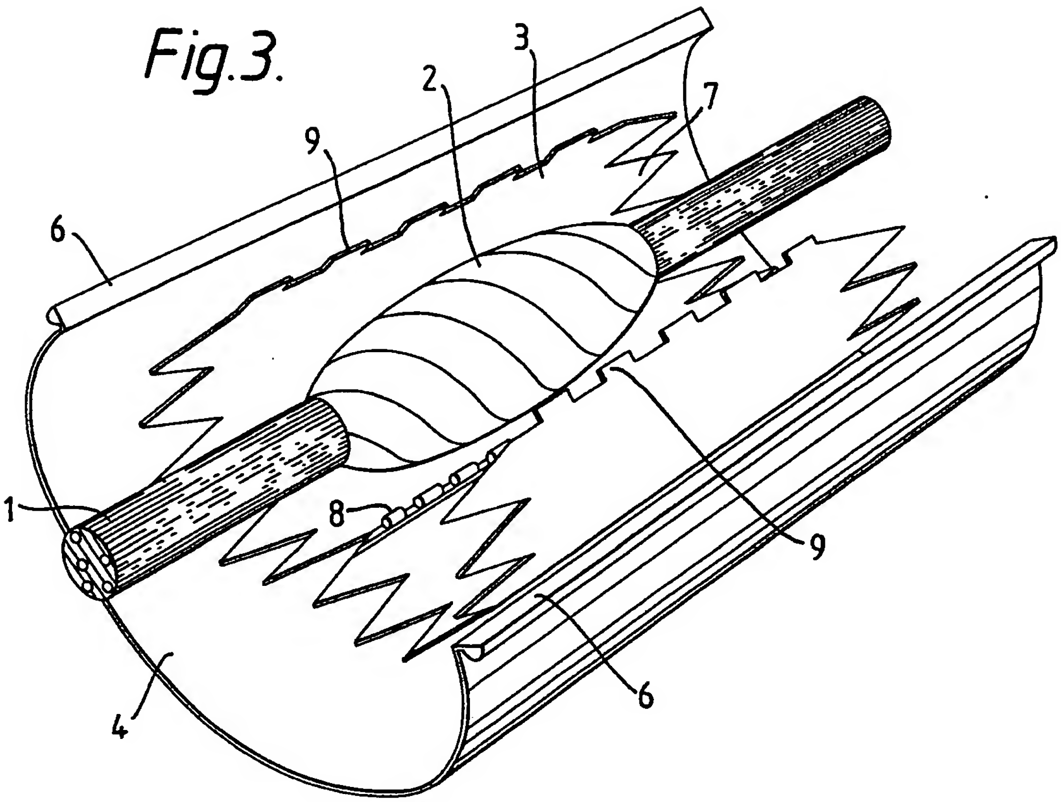


Fig.4.

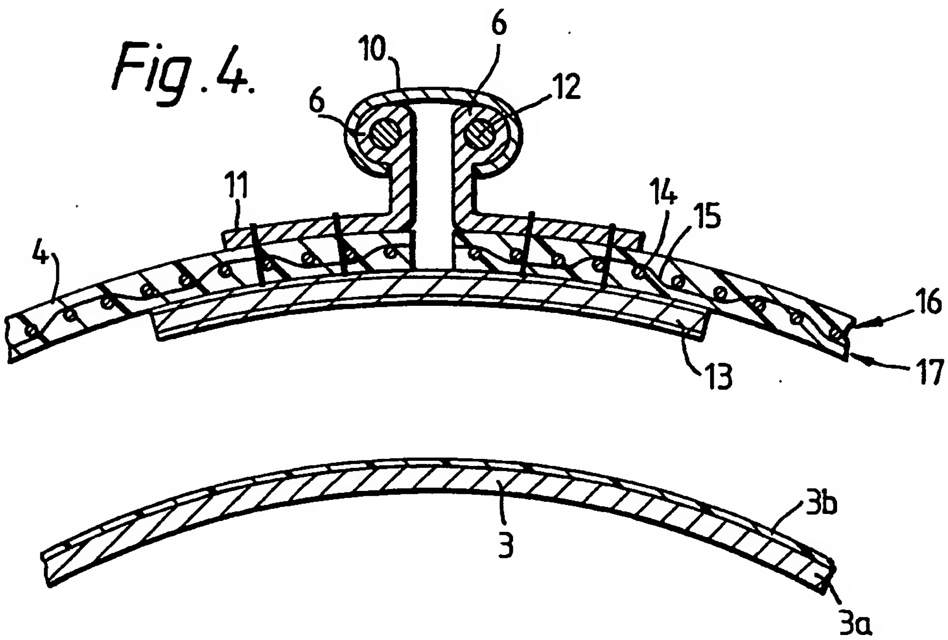


Fig.5a

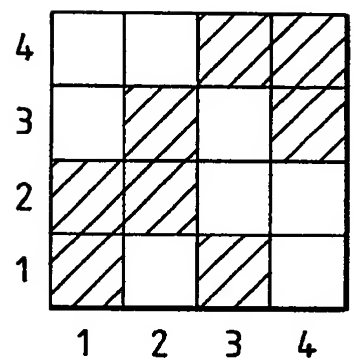


Fig.5b.

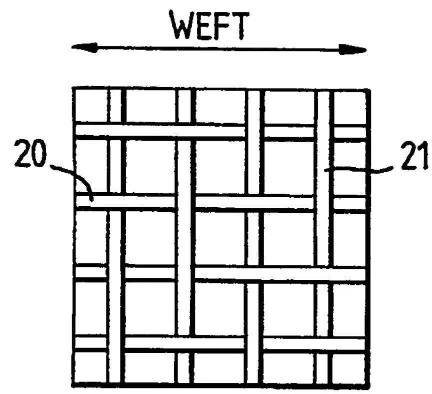


Fig.6a.

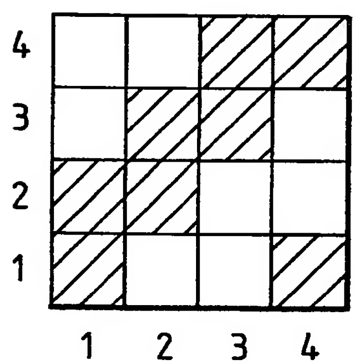


Fig.6b.

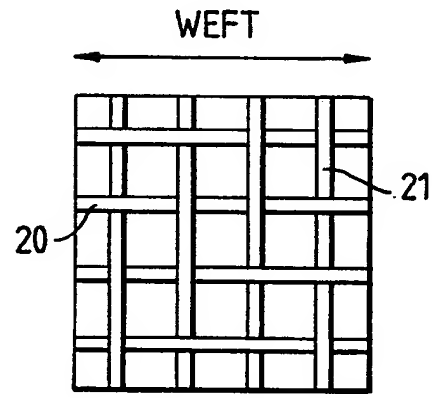


Fig.7a.

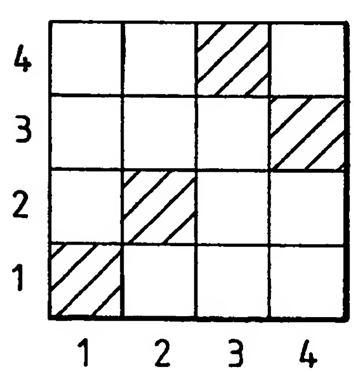
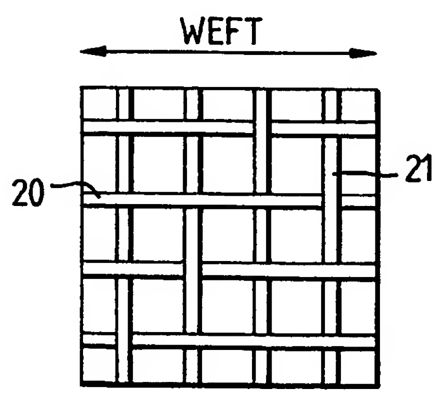


Fig.7b.



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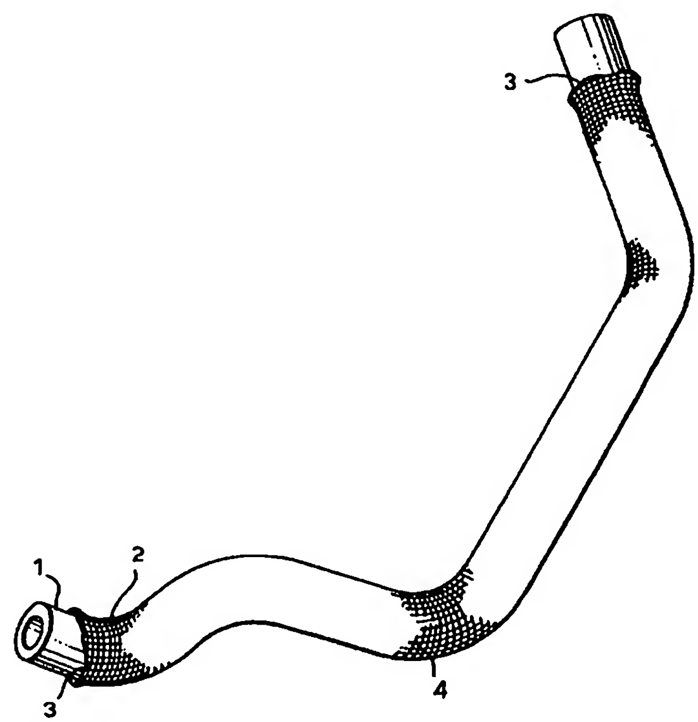
(54) Title: ABRASION PROTECTION

(57) Abstract

The use of a fabric sheath (2), or other article, on a conduit (1), for example a pipe or flexible hose, to provide abrasion resistance or other forms of protection, for example impact protection or cut-through protection, thereto; and fabric sheath suitable for such use. A preferred form of circumferentially-heat-shrinkable sheath of woven fabric, capable of use on a conduit, for example to provide impact cushioning and/or abrasion resistance, provides a substantially unobscured outer fabric surface and comprises hoop filaments extending substantially circumferentially around the sheath, at least some of which hoop filaments are heat-shrinkable, and length filaments extending substantially along the sheath, wherein the length filaments are selected *either (A)* to be sufficiently flexible, at least at temperatures to which they are subjected during heat-shrinking of the sheath in use, for the heat shrinkage of the hoop filaments to crimp the length filaments to an extent (a) producing at least 1 %, preferably at least 2 %, more preferably at least 5 %, longitudinal shrinkage of the sheath in addition to any longitudinal heat shrinkage thereof and/or (b) causing portions of the length filaments either (i) to project outwardly from the shrunken fabric sheath to a maximum distance in excess of the maximum projection distance of the thus-shrunken hoop filaments, or (ii) to increase such excess projection distance if already existing before the heat shrinkage; *or (B)* to be sufficiently stiff to limit the longitudinal shrinkage due to crimping of the length filaments to less than 10 %, preferably less than 5 %, more preferably less than 2 %, especially less than 1 % or substantially zero.



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ABRASION PROTECTION

The present invention relates to the use of a fabric sheath, or other article, on a conduit, for example a pipe or flexible hose, to provide abrasion resistance or other forms of protection, for example impact protection or cut-through protection, thereto, and relates to fabric sheaths suitable for such use. One aspect of the invention relates to circumferentially-heat-shrinkable sheaths of woven fabric for use in providing abrasion protection to conduits. The conduits may be fluid or electrical conduits, or other elongate guiding forms, such as electrical wiring bundles or harnesses, or electrical or optical cables.

Mechanical protection of hoses etc. is often found to be necessary because it is difficult to provide all of the desired properties in a single material. For example, a hose must in general be impermeable to fluids, flexible and heat-resistant. The preferred materials for providing those properties often have poor abrasion and cut-through resistance.

US 5413149 (Bentley Harris) discloses a flexible, kink-resistant shaped fabric product for protecting and/or covering cables, conduits and wiring etc. The shaped fabric has a wall portion comprising a filament resiliently set in a spiral configuration with respect to the longitudinal axis of the shaped product. The wall portion may also comprise a filament in the form of circumferential hoops substantially conforming in shape and size to the cross-sectional configuration of the shaped product. To achieve the resilient set, thermoplastic filaments are heated to a temperature above their glass transition point and are then cooled to cause recrystalization or "set" of the filaments. The resulting product then has the desired spiral resilient bias. This is stated to be an "elastic memory". Whilst the products disclosed in US 5413149 are satisfactory for many purposes, we have found that it may be difficult to locate the products on the conduit to be protected. In general some fixing means such as a small length of heat-shrinkable tubing will be required at each end of the product.

A further prior art product, known as "Expando", is also disclosed in US 5413149. This product is an open braid that when compressed longitudinally expands radially, and vice versa. It is therefore longitudinally compressed, pushed over a hose to be protected, and then longitudinally stretched. The ends must, however, be secured in position by some additional means.

I have now discovered an alternative approach to abrasion resistance which makes use of heat-shrinkage of a fabric product, and one aspect of the present invention accordingly provides the use of a heat-shrinkable fabric sheath to provide abrasion resistance or impact resistance or cut-through resistance to a conduit, for example a pipe or flexible hose.

It should be noted that, although "heat-shrinkage" makes use of the property of "elastic memory", the resilient set disclosed in US 5413149 does not result in a heat-shrinkable sheath. In fact, since it is a spiral configuration that is locked in by the process of setting, the effect of heat on the prior art product would, if anything, result in its radial expansion. In this respect, and in others, the prior art clearly teaches away from the present invention.

Various fabric designs may be employed in the present invention, but I prefer to use a weave, in particular a plain weave, although other weaves such as a 2/2 twill would be suitable. When using a weave, I prefer that one set of fibres runs substantially parallel to the length of the sheath, and another set of fibres runs substantially circumferentially of the sheath. If the sheath is to be made continuously in line, it will be desirable (at least when using a narrow fabric loom) for the warp fibres to become the longitudinal fibres of the sheath, and the weft fibres to become the circumferential fibres of the sheath.

By using a fabric for abrasion resistance, it is possible to select as circumferential fibres those that are ideal for the provision of heat-shrink properties, and to select for the longitudinal fibres those which are ideal for provision of abrasion-resistance, for example toughness, resistance to notch propagation, low coefficient of friction, impact resistance,

and high temperature performance. Such fibres preferably predominate on an external surface of the sheath. Thus, I prefer to use high density polyethylene (HDPE) as the circumferential fibres and to use a polyester, such as polyethylene terephthalate, or a nylon in the warp direction. Other suitable circumferential fibres include polyolefins such as low density polyethylene, medium density polyethylene, polypropylene/polyethylene copolymers and fluoropolymers such as polyvinylidene difluoride (PVDF) and ethylene chlorotrifluoroethylene (E-CTFE). Other suitable longitudinal fibres include polyacryonitrile and copolymers thereof, polyphenylene sulphide, cellulose acetate, aromatic polyamides, eg Kevlar, natural fibres and fluoro polymers. The longitudinal abrasion-resistant fibres are preferably able to flatten-out and/or to move under the influence of an adjacent surface. This ability to flatten-out or to move results in that surface causing less damage to the fibres. To this end I prefer that the longitudinal fibres comprise multi-filament bundles since the filaments within each bundle will be able to move slightly with respect to one another. At present I prefer to use a co-mingled yarn. A further advantage of multifilament bundles is that cut-through of any filament results in less overall damage to the product. The circumferential, heat-shrinkable, fibres may comprise simple monofilaments.

Various preferred characteristics of the product can be achieved by suitable selection of the weave density, weave design, and weaving process. For example, in order to protect the underlying hose against abrasion or cut-through by sharp objects, I prefer that a high-density weave, or weave using fibres of high tex value, be used to achieve a high optical coverage. Optical coverage is a well-known term that simply relates the percentage of a plan view of a fabric that is taken up by the fibres themselves, rather than by the interstices between then. The optical coverage, at least after shrinkage is preferably at least 75%, more preferably at least 95%, most preferably substantially 100%.

A second preferred characteristic of a fabric is that it be ribbed, preferably warp ribbed. This means that the fabric will have a surface relief comprising a series of parallel ribs. If the hose is to be protected from abrasion caused by an adjacent surface moving longitudinally with respect to the hose, it will generally be preferable for ribs to be

provided that run circumferentially of the hose. Ribbed fabrics are well understood in the weaving art, and warp ribbed fabrics may be constructed by inserting several weft picks in succession into the same shed of an ordinary plain weave. A warp ribbed fabric will in general be woven with a larger number of ends than picks. The weft yarn generally has less twist than the warp yarn and is of heavier linear density, and if it is a single monofilament it will have zero twist.

Crimp is another characteristic of the fabric that may be considered. Preferably the crimp is predominantly in the longitudinal direction of the sheath.

Although it will depend on the tex value of the fibres, for most purposes the following weave densities will be suitable. 25-60, particularly 35-45 warp ends per cm, and 3-20, particularly 10-15 weft picks per cm. As mentioned above, the circumferential fibres are preferably monofilaments, and the longitudinal fibres preferably comprise multifilament bundles. More particularly, the longitudinal fibres comprise five to ten fold (particularly about seven fold) bundles, each of the fibres within each bundle again comprising a bundle of very fine filaments. Each of the folds is preferably 10-20 tex, (preferably about 17 tex (tex being the ISO standard for linear density of textile strands and is the weight in grams of 1000 m) and each of those filaments preferably comprises 30-40 very fine filaments. This results in longitudinal fibres of great flexibility and of great ability to flatten out and to move under the abrading effect of an adjacent surface. Damage to any one filament will not of course be catastrophic. The circumferential fibres preferably have a tex value of 5-200, more preferably 20-100, especially 30-60.

One advantage over the cited prior art was stated above to be that the sheath of the invention is easy to secure in place around the hose to be protected. The sheath may be produced in long lengths, cut to length, slid over the hose and then heat-shrunk around the hose to locate it in position. The desired shrinkage ratio for this purpose is from 1.2:1 to 5:1. The lower value will be suitable where the hose to be protected is straight and where installation at low tolerances is simple. Shrink ratios greater than, say, 5:1 might be difficult to achieve in practice and might result in instability or uneven shrinkage during

installation. In general I prefer a shrink ratio between 1.5:1 and 4:1. Where the sheath is to be installed around a shaped, non-linear hose it may be desirable to provide some longitudinal shrinkage to avoid wrinkling at the bends in the hose. To this end I can include heat-shrinkable fibres in the longitudinal direction. A longitudinal shrinkage ratio of from 1-20%, more preferably 2-10%, will generally be suitable. Shrinkage when expressed as a ratio means a dimension before shrinkage compared to the dimension after shrinkage. When expressed as a percentage it means the change in a dimension, based on the dimension before change.

Where the sheath is produced in long lengths it will usually require cutting before installation. This can conveniently be done by a hot blade such as a hot knife, which not only cuts the fibres but welds them together at the new end of the sheath to prevent fraying. It is therefore desirable that the fibres be thermoplastic, and therefore not excessively cross-linked during their manufacture.

Some degree of cross-linking of at least some of the fibres of the sheath may be desirable to render the sheath heat-shrinkable. The circumferential fibres, which by virtue of their heat-shrinkability, drive shrinkage of the overall product, are preferably cross-linked and stretched before weaving of the fabric. They may be cross-linked and then stretched at an elevated temperature and then cooled, or the heating, stretching and cooling may precede the cross-linking. Generally it will be desirable to weave the fabric from heat-shrinkable fibres, although in some circumstances it may be preferred to produce the fabric from heat-stable fibres, and then stretch the fabric. Depending on the temperature performance of the product it may be desirable to cross-link the fibres which are, or are to become, heat-shrinkable before weaving in order that the longitudinal fibres may remain uncross-linked. In this way, the longitudinal fibres can readily be welded at their ends by the hot-knife cutting. Where higher temperature performance is required it may be desirable to cross-link the overall fabric (either by cross-linking separately all of the fibres from which it is to be made, or by cross-linking the woven fabric) in order to ensure that all of the fibres retain their integrity at high temperatures.

The sheath may be produced in the form of a tube, or other structure closed in cross-section or it may be woven as a sheet and later formed into a tube either before or during installation. A product formed into a tube during installation, known as a "wraparound sleeve" may be provided with a so-called closure mechanism to hold it in the wrapped around configuration around the hose.

If desired the sheath may be provided with some form of visual marking either for identifying it or as a means of determining when it has been subjected to abrasion. For example, a logo of distinguishing colour may be woven into the sheath using for example a Jaquard mechanism on a narrow fabric or other weaving machine. Such a logo may serve to identify the product as that of a particular company, it may be provided for aesthetic reasons, or it may be provided to indicate the nature of the fluid that the underlying hose is carrying. For example, hoses containing dangerous fluids or hoses that will become hot during use may be provided with a marking in red etc. by way of a warning.

Indication of abrasion may be provided as follows. Abrasion-susceptible fibres may be woven into the sheath such that they predominate on the external surface of the sheath that is likely to become abraded. If these abrasion-susceptible fibres are of a distinguishing colour with respect to the remainder of the sheath then the appearance of the sheath will change as it becomes abraded. Full protection of the underlying hose may continue to be provided long after the sacrificial fibres have been destroyed. Thus, periodic inspection will reveal that abrasion has occurred and will alert someone to take suitable action, either to prevent a further abrasion or to replace the now partly worn sheath.

Various other characteristics may be built into the design of the sheath depending on the nature of the hose to be protected. For example, the materials may be chosen to ensure high temperature performance, oil resistance, acid resistance, and resistance to a variety of other chemicals.

Example

A heat-shrinkable fabric sheath was provided as follows. A narrow fabric loom was used to produce a heat-shrinkable fabric sheath of 3cm diameter in a plain weave having lengthwise warp and circumferential weft. The weft was a cross-linked high density polyethylene monofilament of 43.4 tex and the warp fibres consisted of seven fold polyethylene terephthalate multifilaments, each of the seven filaments itself consisting of thirty four very fine filaments. Each of the seven multifilaments had a tex value of 16.7. The warp density was 38 ends per cm and the weft density was 13 picks per cm.

A section of sheath of length 25 cm was cut by means of a hot knife causing the polyethylene terephthalate warp fibres to weld together to prevent fraying. The sheath was slid over a rubber hose of 1cm diameter and was then shrunk in place. The hose was pre-shaped and the sheath shrunk to follow the contours of the shaped hose without wrinkling.

An abrasion test was carried out using a modified form of scrape test BS5173 using both a flat blade and a pointed blade. The flat blade was weighted with 500g and the pointed blade weighted with 200g. The tests were carried out at 100°C. In each case no damage whatsoever had occurred after 4000 cycles.

rk571 ABRASION PROTECTION

The fabric of these sheaths comprises filaments extending substantially circumferentially around the sheath (hereinafter "hoop filaments"), at least some of which hoop filaments are heat-shrinkable, and filaments extending substantially along the sheath (hereinafter "length filaments"), and it is mentioned that some degree of longitudinal shrinkage, to avoid the problem of wrinkling of the sheath at bends in the conduits, may be provided by incorporating heat-shrinkable fibres extending in the longitudinal direction.

The present invention ingeniously addresses this wrinkling problem by providing a circumferentially-heat-shrinkable sheath of woven fabric, capable of use on a conduit, for example to provide abrasion resistance as described and claimed in co-pending British Patent Application No. 9612667.7 (RK556), wherein the sheath provides a substantially unobscured outer fabric surface and comprises hoop filaments extending substantially circumferentially around the sheath, at least some of which hoop filaments are heat-shrinkable, and length filaments extending substantially along the sheath, which length filaments are preferably dimensionally substantially heat-stable, and wherein the length filaments are selected *either* (A) to be sufficiently flexible, at least at temperatures to which they are subjected during heat-shrinking of the sheath in use, for the heat shrinkage of the hoop filaments to crimp the length filaments to an extent (a) producing at least 1%, preferably at least 2%, more preferably at least 5%, longitudinal shrinkage of the sheath in addition to any longitudinal heat shrinkage thereof and/or (b) causing portions of the length filaments to project outwardly from the shrunken fabric sheath to a maximum distance greater than the maximum projection distance of the thus-shrunken hoop filaments *or* (B) to be sufficiently stiff to limit the longitudinal shrinkage due to crimping of the length filaments to less than 10%, preferably less than 5%, more preferably less than 2%, especially less than 1% or substantially zero.

The (preferred) longitudinal shrinkage of the sheaths due to crimping of the length filaments by the heat-shrinking hoop filaments (hereinafter "crimp shrinkage" for brevity) and/or the greater projection of the length filaments after heat-shrinkage of the sheath (hereinafetr "crimp hiding" of the hoop filaments) may be achieved or enhanced by holding the length filaments under tension during weaving of the fabric, so as to resist (to a desired extent) crimping by the relatively low weaving tension of the hoop filaments. In tubular weaving processes, the hoop filament tension is maintained as low as practicable to avoid undesired constriction of the tubular sheath as it is progressively formed. If the length filaments are already crimped in the fabric as woven, the heat-shrinking of the hoop filaments may nevertheless tend to produce useful longitudinal crimp shrinkage and/or crimp hiding owing to the accompanying increase in hoop filament thickness which increases the depth of the initial crimp in the length filaments.

The alternative of using relatively stiff length filaments to limit the crimp shrinkage may be useful to enable selection of a uniquely controllable degree of crimp shrinkage, using the stiffer length filaments alone or together with more flexible length filaments. Controlled crimp shrinkage may be especially useful in applications where the final length of the sheath is required to match a specific length of conduit on which it is used. Suitable stiffer length filaments may be selected by simple trial and error, for example from plastics monofilaments or possibly glass filaments.

It is preferred to construct the fabric sheath so that it will have longitudinal crimp shrinkage within the range from 10 to 20 % on unrestricted circumferential heat-shrinkage (that is shrinkage to its fullest extent without any conduit or other substrate inside the sheath). In use, the crimp shrinkage will normally be less than the unrestricted maximum, due to the presence of such a conduit or substrate, which will halt the circumferential shrinkage, and thus also the crimp shrinkage, at an intermediate stage as the sheath tightens around it. Preferably there will be negligible longitudinal heat-shrinkage, for example less than 5%, preferably less than 2%, more preferably not more than 1%.

It is observed that the parameters responsible for producing the crimp shrinkage are dominated by the flexibility of the length filaments, which will preferably be evident at ambient temperatures, but may be provided by length filaments which are relatively stiff and inflexible at ambient temperatures, but become adequately more flexible at temperatures to which they are subjected during the heat-shrinking of the sheath in use. Other fabric parameters, such as weave design, number of weft insertions, or number of warp ends, tend to have relatively little effect on the crimp shrinkage of the length filaments and/or crimp hiding of the hoop filaments. For example, a weave design in which the length filaments pass over three hoop filaments (so-called "3-in-1") may produce less initial crimp in the length filaments than would occur in a plain "1-in-1" weave. Fewer weft insertions per unit length and/or fewer warp ends per unit length may tend to increase the longitudinal crimp shrinkage, while too many of either may produce a fabric in which the desired heat-shrinkage is hindered by undesirably tight weaving. Thus,

a balance may be struck to some extent by simple trial and error between the looseness or tightness of the weave and the degree of additional crimp shrinkage desired. However, these factors are minor compared with the effect of the length filament flexibility on the degree of crimp shrinkage and/or crimp hiding achieved in practice.

The tension and flexibility of the length filaments will preferably be sufficient to cause them to project outwardly from the fabric to a lesser extent than the hoop filaments, which hoop filaments will therefore tend to undulate over and under the relatively straighter length filaments. The length filaments will preferably be woven to project outwardly from the fabric to a maximum distance less than 85%, preferably less than 70%, more preferably less than 55%, of the maximum projection of the hoop filaments.

The heat-shrinkage forces of the hoop filaments will preferably be sufficient to crimp the length filaments to an extent which causes them to project outwardly from the shrunken fabric sheath to a maximum distance greater than, preferably at least 25% greater than, more preferably at least 50% greater than, especially at least 75% greater than, the maximum projection distance of the shrunken hoop filaments. It is advantageous for the flexibility of the length filaments and the shrinkage forces of the hoop filaments to be sufficient to cause the crimped length filaments subsatntially to conceal the shrunken hoop filaments after the heat-shrinking step. This "hiding" or "burying" of the hoop filaments on heat-shrinking of the sheath enables the length filaments to be selected for their abrasion-resisting properties; and the hoop filaments to be selected for optimum heat-shrink properties without too much regard to abrasion resistance, which may not always be easy to combine with preferred levels of heat-shrink performance. As a result of the more abrasion-resistant length filaments thus being predominantly exposed on the surface of the sheath after shrinking, the abrasion resistance may be effectively increased relative to that of the unshrunk sheath, in addition to the desirably close fit around the conduit achieved by the heat-shrinking operation.

The projection distances may be understood as being measured to the outermost surface of the hoop or length filaments, whichever is on top as they pass over and under

each other. In a plain weave, the hoop and length filaments pass alternately over and under each other, so that the projection distance of a hoop filament where it passes over one of the length filaments may be compared with the projection distance of that same length filament where it passes over the immediately adjacent hoop filament. The projection distances may be measured from any convenient fixed point, for example a plane lying parallel with the fabric and contacting the innermost points of the inner fabric surface, or a similar plane passing through the mid-point of the fabric thickness. It may be preferable in practice to measure the average incremental projection distance of whichever filaments (hoop or length) project further outwards, measured from the outermost surface of the adjacent less-outwardly-projecting other filaments (length or hoop) at their point of maximum projection.

It will be understood that the reference to circumferentially-heat-shrinkable sheaths does not necessarily limit the invention to tubular sheaths of substantially circular cross-section. Sheaths of square, triangular, hexagonal, or any other desired tubular cross-section, whether woven as tubes or formed by wrapping around and fastening a fabric originally woven as a sheet, may be included, provided that they are heat-shrinkable in the direction of the perimeter so as to narrow the tube, thus enabling them to contract around and grip the conduits to which they provide abrasion resistance in use. The requirement that the sheath provides a substantially unobscured outer fabric surface will be understood as excluding sealed heat-shrinkable fabrics whose external surface is covered with a layer of polymeric material of at least 0.03 mm thickness, as described for example in EP-A-0117026 (RK176), but may include fabrics with coatings from which at least parts of the filaments project to provide an abrasion-resisting contact function in use.

The hoop filaments in this aspect of the present invention extend substantially circumferentially around the sheath, as distinct from the helical filaments of a braid, which extend very noticeably along the sheath as well as around it. The length filaments of the fabric according to the present invention extends substantially along the sheath, preferably substantially parallel with the sheath tubular axis, although a certain amount of helical curvature of these length filaments may be tolerable in practice and is to be understood as

included within the expression "substantially along the sheath". It is generally preferred, though not essential, that the hoop filaments are provided by the weft of the fabric and the length filaments are provided by the warp of the fabric.

The invention also includes a method of making the sheaths hereinbefore described by weaving with the length (preferably warp) filaments held under sufficiently high tension and the hoop (preferably weft) filaments under sufficiently low tension to produce the aforesaid crimp shrinkage effect.

The length filaments are preferably multi-filament yarns, especially substantially-untwisted tows, for enhanced abrasion resistance, as mentioned in the aforesaid co-pending application. Multi-filament yarns tend to spread out to enhance their surface coverage, while their degree of surface projection from the sheath may be only a few multi-filaments deep, thus advantageously reducing the degree of strain imposed on the filament material at outside bend radii. The spreading and flexibility of multi-filaments yarns may also produce advantageous softness and noise-deadening impact insulation effects to reduce rattling in vehicles and other end uses. Mono-filaments or tape-like length filaments could nevertheless be used, provided they are flexible enough to provide a useful degree of crimp shrinkage and/or crimp hiding. The exact degree of flexibility is not readily quantifiable, but will generally be greater than that of relatively brittle materials such as glass fibre and can readily be tested by trial and error in practice. Lower flexibility may to some extent be better tolerated as the diameter of the filaments decreases.

It is an advantage of the crimp shrinkage feature of the present invention that reduction or prevention of sheath wrinkling at bends in the conduit to be protected can be achieved with little (e.g. less than 5%, preferably less than 2%, more preferably less than 1%, or substantially no, longitudinal heat shrinkability of the fabric sheath.

The fabric of the sheath may usefully be woven so as to provide the sheath before shrinking with a degree of longitudinal stretch, preferably less than 10%, more preferably within the range from 0.5% to 5%, especially 1% to 3%. Such longitudinal stretch may

enable the sheath better to accomodate stretching around the outside of bends in the conduit onto which it is fitted in use, thus facilitating initial positioning on the conduit and co-operating with the wrinkle-removing effect of the crimp shrinkage on the inside of the bends to enhance the appearance of the final shrunken sheath thereon. Such longitudinal stretch may be influenced by the length filament structure, softer multi-filament yarns for example tending to give greater stretch, and by the weave design, the aforementioned looser "3-in-1" weaves for example tending to allow greater stretching than tighter plain weaves.

Specific embodiments of the invention will now be described by way of example with reference to the accompanying schematic drawings, wherein:-

Figure 1 shows a shaped rubber automotive hose protected by a surround heat-shrunk fabric sheath.

Figure 2 illustrates an idealised end view of a tubular fabric sheath according to the invention having heat-shrinkable hoop filaments and straight length filaments;

Figure 3 shows the sheath of Fig. 2 after heat shrinking of the hoop filaments;

Figures 4 and 5 show in idealised perspective a small section of the sheath fabric before and after heat shrinking;

Figure 6A shows an idealised edge view of the fabric of Fig. 2, showing one straight length filament and looking along the hoop filaments;

Figure 6B shows the fabric of Fig. 6A after heat shrinking; and

Figure 6C shows a less-idealised version of Fig. 6A, in which the length filament is not perfectly straight.

Referring to the drawings, in Figure 1 the hose is designated 1, the sheath 2, and the cut and sealed ends of the sheath 3. Circumferential ribs 4 can be seen along the length of the sheath.

Fig. 2 shows a sheath having notionally straight length filaments 10 formed by the warp of a plain weave under suitably high weaving tension, and shows two of the heat-shrinkable hoop filaments 12, 14 adjacent to each other formed by the weft, giving the

substantially circular sheath an outer diameter D. At this stage, it can be seen that the hoop filaments 12, 14 project further outwards than the length filaments 10 by a distance ΔP, which is approximately equal to the thickness of the hoop filaments in this idealised construction having straight length filaments. Figure 3 shows the sheath of Fig. 2 after the hoop filaments 12, 14 have been heat shrunk, thus reducing the sheath diameter by an amount ΔD. The ends of the multi-filament length filaments 10 which were visible between the hoop filaments 12, 14 in Fig. 2 are now on opposite sides of the single visible hoop filament 12, the other hoop filament 14 now being obscured behind the visible filament 12 owing to both hoop filaments now being notionally straightened by their heat recovery forces, thus crimping the length filaments 10 so that further portions 16 of the length filaments 10 are now visible where they pass over the obscured rear hoop filament 14.

Figures 4 and 5 illustrate in idealised perspective the lengthwise crimp shrinkage of the length filaments 10 resulting from the circumferential heat shrinkage of the hoop filaments 12, 14, 18. The straightening of the undulating hoop filaments 12, 14, 18 of Fig. 4 induces crimping of the originally straight length filaments 10 as shown in Fig. 5, thus reducing the length L of the sheath fabric by an amount ΔL.

Figures 6A to 6C illustrate the crimp shrinkage in another view, looking sideways at a length filament 50 of length L, behind which can be seen (in Figs. 6B and 6C) another length filament 52. The hoop filaments 60 can be seen above and below the notionally straight length filament 50 in Fig. 6A, with further portions 62 of the hoop filaments visible where they pass over the concealed length filament 52. The hoop filaments project outwards further than the length filaments by a distance ΔP, roughly equal to the hoop filament thickness as before. After heat shrinking of the hoop filaments 60, the length filaments 50, 52 are crimped, reducing the sheath length by an amount ΔL as shown in Fig. 6B, as the hoop filaments 60 pull themselves inwards and become relatively straighter. The length filaments 50, 52 now project outwardly by a greater distance $\Delta P'$ than the hoop filaments 60. In reality, the length filaments 50, 52 are unlikely to be woven perfectly straight in the unshrunken fabric sheath, and may tend to undulate

somewhat over and under the hoop filaments 60 (and their nether portions 62), as shown in Fig. 6C. In that case, the incremental projection $\Delta P''$ of the unshrunk hoop filaments will be less than that shown as ΔP in Fig. 6A. Also, the unshrunken sheath length L' will be less than the notional length L of Fig. 6A, so that the lengthwise crimp shrinkage may be proportionally smaller when the hoop filaments are heat shrunk.

CLAIMS

1. The use of a heat-shrinkable fabric sheath to provide abrasion resistance to a conduit.

2. The use according to claim 1, in which the conduit comprises a flexible hose.

3. The use according to claim 1 or 2, in which the fabric comprises a weave having fibres running substantially parallel to the length of the sheath, and fibres running substantially circumferentially of the sheath.

4. The use according to claim 1, 2 or 3, in which the fabric after shrinkage has an optical coverage of at least 75%.

5. The use according to any preceding claim, in which the sheath has a circumferential shrinkage ratio of from 1.5:1 to 4:1.

6. The use according to any preceding claim, in which the sheath has a longitudinal shrinkage ratio of from 1 to 20%.

7. The use according to any preceding claim, in which the fabric has a crimp that is predominantly in the longitudinal direction of the sheath.

8. The use according to any preceding claim, in which the fabric is ribbed, having its ribs running substantially circumferentially of the sheath.

9. The use according to any preceding claim, in which the fabric is a weave having its warp in the longitudinal direction of the sheath.

10. The use according to any preceding claim, in which the longitudinal fibres comprise co-mingled yarn.

11. The use according to any preceding claim, in which the circumferential fibres comprise monofilaments.

12, The use according to any preceding claim, in which the fabric comprises a weave having 25-60 warp ends per cm.

13. The use according to any preceding claim, in which the fabric comprises a weave having from 3-20 weft picks per cm.

14. The use according to any preceding claim, in which fibres which predominate on an external surface of the sheath comprise a polyester or a nylon.

15. The use according to any preceding claim, in which the sheath is heat-shrinkable by virtue of heat-shrinkable polyethylene fibres thereof.

16. The use according to any preceding claim, in which the sheath is cut-to-length by means of a hot blade.

17. A circumferentially-heat-shrinkable sheath of woven fabric, capable of use on a conduit, for example to provide impact cushioning and/or abrasion resistance, wherein the sheath provides a substantially unobscured outer fabric surface and comprises

hoop filaments extending substantially circumferentially around the sheath,

at least some of which hoop filaments are heat-shrinkable, and

length filaments extending substantially along the sheath,

and wherein the length filaments are selected

either (A) to be sufficiently flexible, at least at temperatures to which they are subjected during heat-shrinking of the sheath in use, for the heat shrinkage of the hoop filaments to crimp the length filaments to an extent

(a) producing at least 1%, preferably at least 2%, more preferably at least 5%, longitudinal shrinkage of the sheath in addition to any longitudinal heat shrinkage thereof and/or

(b) causing portions of the length filaments either

(i) to project outwardly from the shrunken fabric sheath to a maximum distance in excess of the maximum projection distance of the thus-shrunken hoop filaments, or

(ii) to increase such excess projection distance if already existing before the heat shrinkage,

or (B) to be sufficiently stiff to limit the longitudinal shrinkage due to crimping of the length filaments to less than 10%, preferably less than 5%, more preferably less than 2%, especially less than 1% or substantially zero.

18. A sheath according to claim 17, wherein the length filaments are dimensionally substantially heat-stable at temperatures encountered during the heat-shrinkage of the sheath.

19. A sheath according to claim 17 or 18, wherein the hoop filaments are provided by the weft of the fabric and the length filaments are provided by the warp of the fabric.

20. A sheath according to any of claims 17 to 19, wherein the sheath has been rendered more susceptible to the said longitudinal shrinkage (crimp shrinkage) by holding the length filaments under higher-than-normal tension so as to resist crimping of the length filaments during weaving of the fabric, the hoop filaments being held at relatively lower weaving tension during weaving.

21. A sheath according to claim 20, wherein the tension of the length filaments is sufficient to cause them to project outwardly from the fabric to a lesser extent than the hoop filaments.

22. A sheath according to claim 21, wherein the length filaments are woven to project outwardly from the fabric to a maximum distance less than 85%, preferably less than 70%, more preferably less than 55%, of the maximum projection of the hoop filaments.

23. A sheath according to any of claims 17 to 22, wherein the heat-shrinkage forces of the hoop filaments and the flexibility of the length filaments are sufficient to crimp the length filaments to an extent which causes them to project outwardly from the fully shrunken fabric sheath to a maximum distance at least 25% greater than, preferably at least 50% greater than, especially at least 75% greater than, the maximum projection distance of the fully heat-shrunken hoop filaments.

24. A sheath according to any of claims 17 to 23, wherein portions of the hoop filaments are clearly visible from the exterior of the sheath before heat shrinking and the length filaments substantially conceal the hoop filaments from exterior view in the fully heat-shrunken sheath.

25. A sheath according to any of claims 17 to 24, which before shrinking has a degree of longitudinal stretch less than 10%, preferably within the range from 0.5% to 5%.

26. Use of a sheath according to any of claims 17 to 25 according to any of claims 1 to16.

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Fig.1.

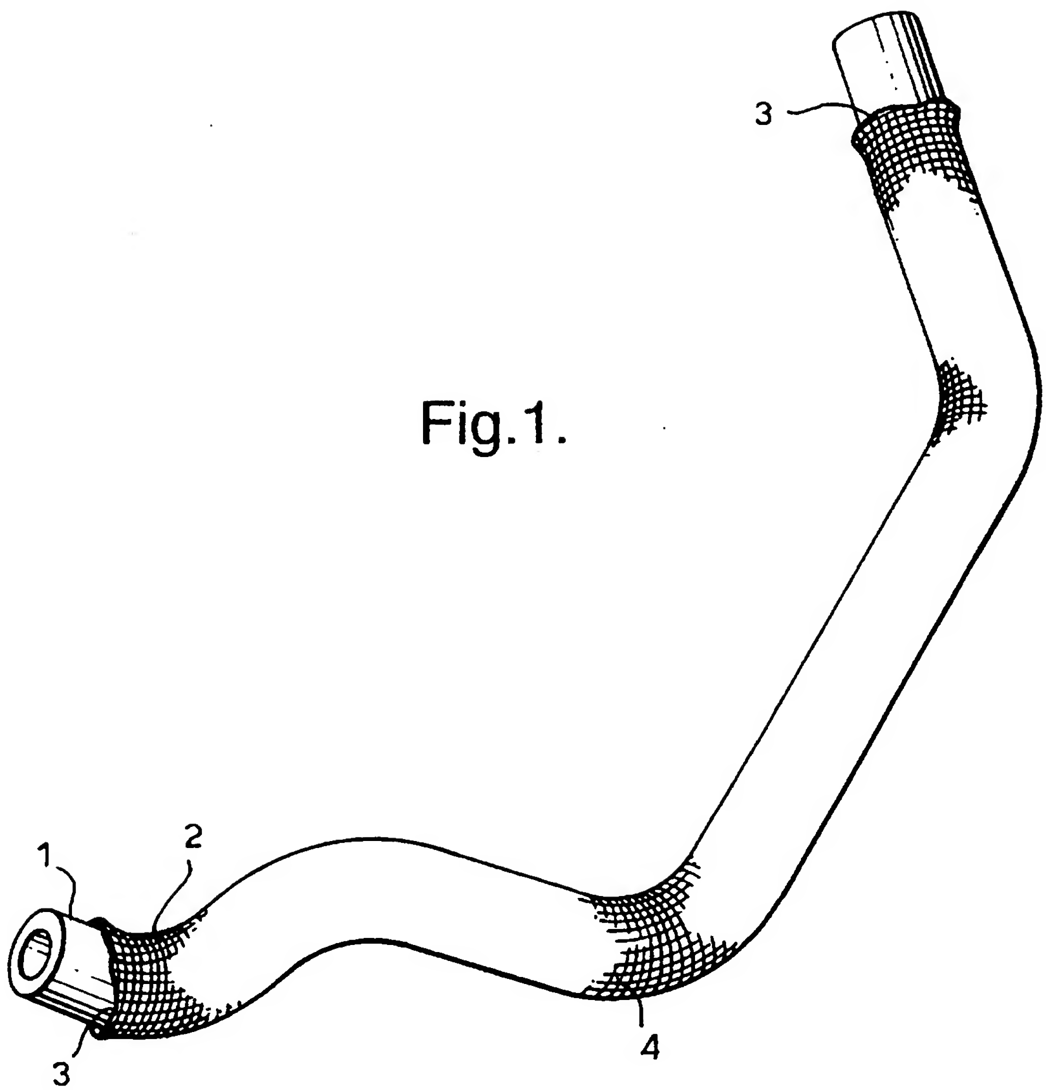


Fig.2.

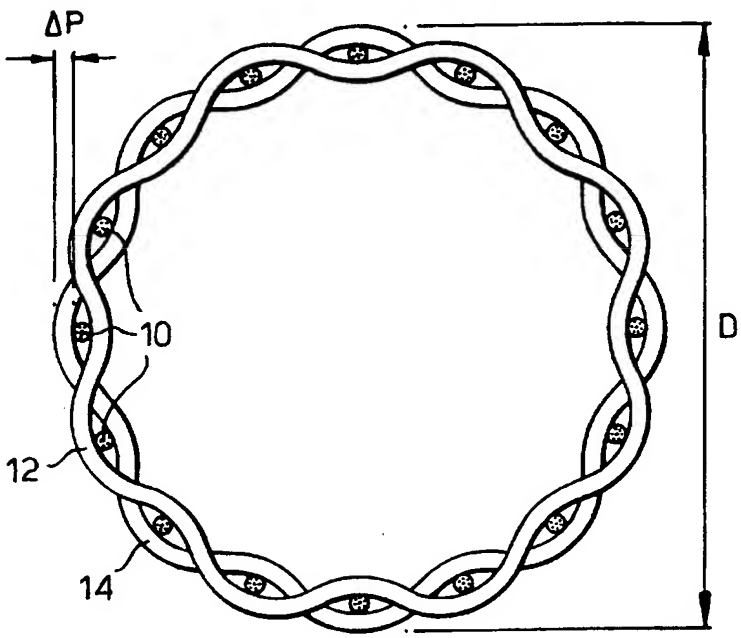


Fig.3.

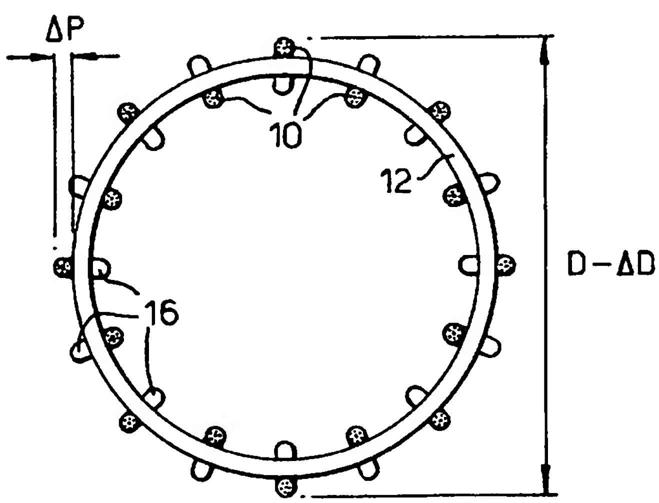


Fig.4.

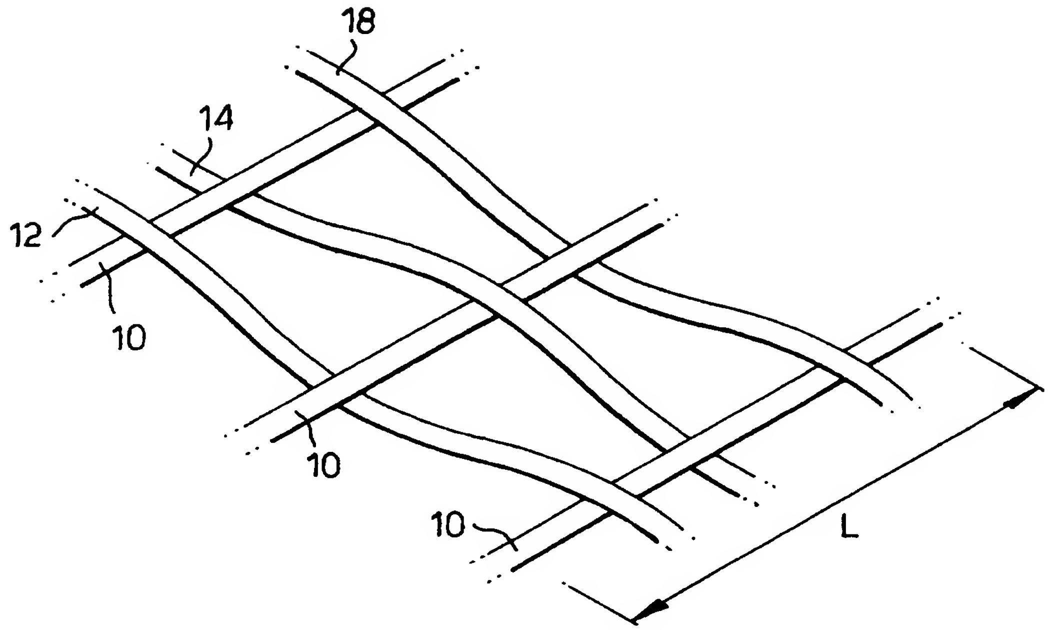


Fig.5.

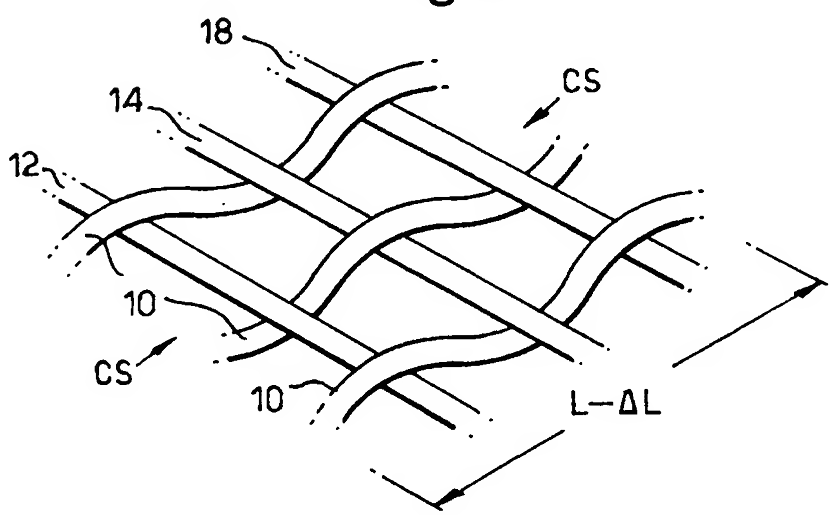


Fig.6A.

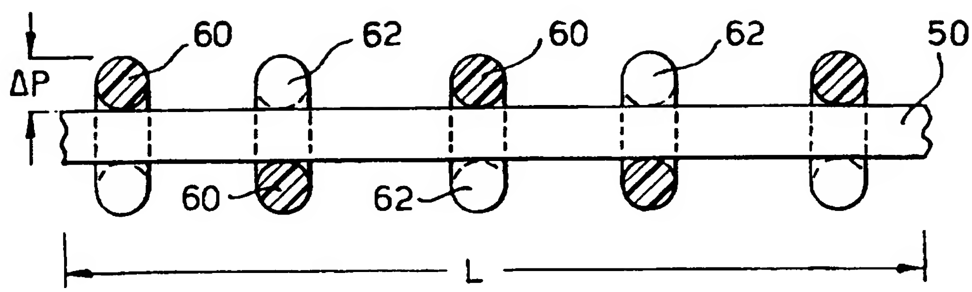


Fig.6B.

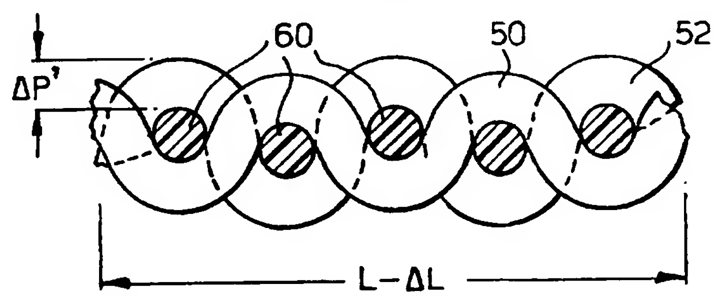
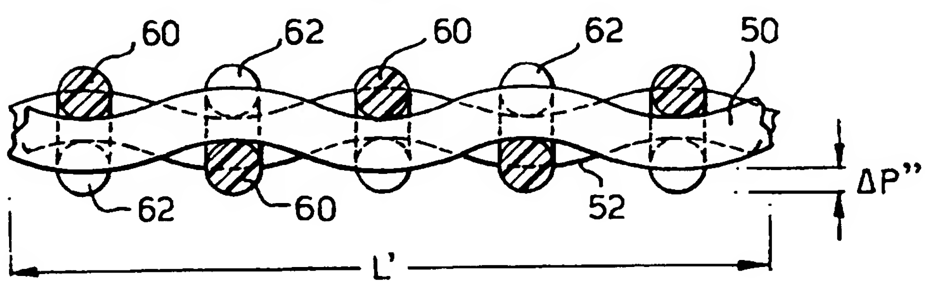


Fig.6C.



INTERNATIONAL SEARCH REPORT

Inter. .onal Application No
PCT/GB 97/01544

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F16L47/00 D03D3/02 B29C61/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F16L D03D B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	GB 2 173 959 A (RAYCHEM LTD) 22 October 1986 see the whole document	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

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Date of the actual completion of the international search	Date of mailing of the international search report
9 September 1997	23.09.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Angius, P

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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